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CONTENTS

ILLUSTRATIONS

TABLES

Agricultural Research Service
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SLOW-RELEASE FORMULATIONS OF ALDICARB

Modeling of Soil Persistence

By J. R. Coppedge, R. A. Stokes, R. L. Ridgway, and R. E. Kinzer[1]

ABSTRACT

Theoretical models developed from data on the persistence of aldicarb in soil were used to predict the requirements for slow-release formulations. The predictions indicated that a slow-release formulation will only be effective if the amount applied exceeds the amount necessary for initial control of a pest population. Also, a slow-release formulation may be the most effective against the insect pests that are most susceptible to a compound. An effective slow-release formulation should decrease the adverse effects of aldicarb on seedling emergence after soil applications. Controlled biological tests with cotton, boll weevils, aphids, and spider mites confirmed the model predictions.

INTRODUCTION

Aldicarb [2-methyl-2-(methylthio)propionaldehyde *O*-(methylcarbamoyl)oxime] is an effective systemic insecticide against several pests of cotton (*18*).[2] In-furrow and side-dress applications provide good control of spider mites, *Tetranychus* spp. (*13, 14, 16*); cotton fleahoppers, *Pseudatomoscelis seriatus* (Reuter) (*8, 10, 14, 15*); lygus bugs, *Lygus* spp. (*2, 15–17*); and the boll weevil, *Anthonomus grandis* Boheman (*6–8, 13, 16, 18*).

Although side-dressing is effective, the method requires special equipment and, particularly against the boll weevil, precise timing, which inclement weather can delay. Moreover, substantial reductions of beneficial insects and subsequently increased populations of the bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *H. virescens* (Fabricius), hereafter referred to as *Heliothis*, have followed side-dressings of aldicarb to cotton. (*3, 6, 19, 20*).

The most practical method of treating cotton with aldicarb is probably in-furrow application at planting with granular applicators, which attach easily to most cotton planters. In addition, in-furrow applications appear to create fewer *Heliothis* problems than side-dress applications (*3, 7, 14*).

Although in-furrow application at planting is more practical, it is less effective than side-dressing against some insect pests. In most areas, cotton must be protected from cotton fleahoppers and boll weevils for a week or more after it begins to square. But when aldicarb is applied in-furrow at rates which do not cause significant stand reductions, usually 1 lb/acre or less (*7, 11, 15*), its effectiveness is greatly diminished by the time squaring begins (*7, 8, 14*). An additional 2 to 3 weeks' activity would substantially improve control of cotton fleahoppers and overwintered boll weevils.

It has been demonstrated that slow-release formulations may extend the biological activity of aldicarb (*9, 21, 22*). We report here studies to further define the requirements of such formulations. First, we considered the factors determining the amount of toxicant in cotton plants after soil applications of aldicarb. Then, we developed two models, one to illustrate the per-

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[2] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

sistence of aldicarb and its toxic metabolites in soil after application at several dosages, and another to predict toxicant levels in soil after application of aldicarb in various theoretical formulations. Finally, we tested the validity of the models in biological experiments.

MODELS OF ALDICARB PERSISTENCE IN SOIL

When aldicarb is applied to cotton as a soil treatment, the amount of toxicant in new growth (growth after treatment) is considerably less than the amount in old growth (growth at treatment) (*4, 5, 18*). The difference is probably accounted for by the degradation of aldicarb to nontoxic metabolites within 2 weeks of application. Moreover, apparently little toxicant is translocated from old to new growth (*5*). If aldicarb could be protected from degradation in the soil and released over an extended time, its continued uptake would result in the new growth being toxic to susceptible insects longer.

The amount of aldicarb in soil at any one time is theoretically the difference between the rate of its release from granules and the rate of its disappearance from the soil. Experiments have indicated that the half-life of the toxicants in a loam soil is about 7 days (Coppedge, unpublished data). If the rate of disappearance is dependent on a continuous function of the concentration in soil and if this rate follows first-order kinetics, a mathematical model can be constructed to predict the concentration of aldicarb in soil at various times after application (*12*) by

$$\log \frac{[C^{\circ}]}{[C]} = \frac{0.30103T}{T\,½},$$

where $[C^{\circ}]$ = initial concentration,
$T\,½$ = half-life (7 days),
and $[C]$ = concentration at time T.

Theoretical levels of toxicant remaining in soil for 48 days were calculated for single additions of 8.5, 17, 34, 68, and 136 mg of aldicarb to 1 gal of soil. These calculations (fig. 1) illustrate that when a conventional fast-release formulation is used, doubling the dose should maintain a specific level of toxicant in the soil for about an additional week. Thus, increasing the dosage appears to be an inefficient method of increasing the length of biological activity of soil applications of aldicarb.

Next, with the same formula, the concentrations of toxicant in soil were calculated for three theoretical applications of aldicarb: 34 mg in a single application; 34 mg in equal daily doses for 20 days; and 34 mg in equal doses for 42 days. The first application represents a conventional fast-release formulation, while the last two represent theoretical slow-release formulations with different release rates. Since it would be extremely difficult to prepare formulations capable of releasing aldicarb in equal increments over a given time, a model including such formulations could not be validated. Certain projections can be made, however, concerning the possible requirements and limitations of slow-release formulations (fig. 2).

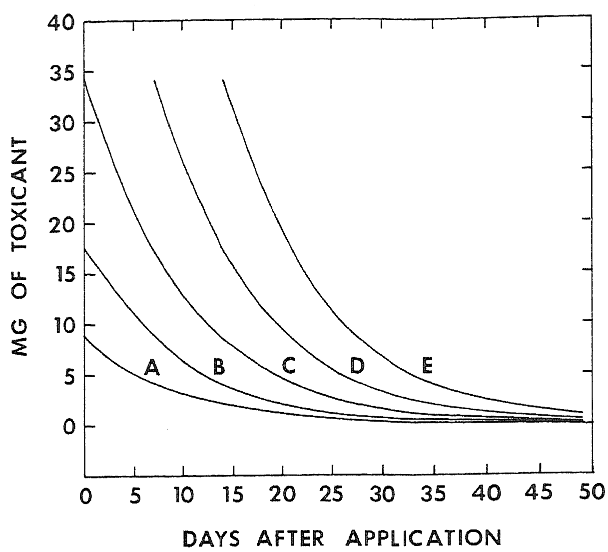

FIGURE 1.—Theoretical levels of toxicant remaining in soil after soil applications of (A) 8.5, (B) 17, (C) 34, (D) 68, and (E) 136 mg of aldicarb.

For a slow-release formulation to be effective, the toxicant added to a system must exceed the amount necessary to give a high initial kill of a pest population. If all the added toxicant is needed for initial control of these pests, a slow-release formulation would be impractical. For example, if a soil concentration of 15 mg of toxicant is required to protect new growth, the fast-release formulation (A) would be more effective than the theoretical slow-release preparations (fig. 2). However, if a soil concentration of only 10 mg is required, formulation B, which releases toxicant over 20 days, would be the most effective. If only 5 mg is required, then formulation C, which releases toxicant over 42 days, would be the most effective.

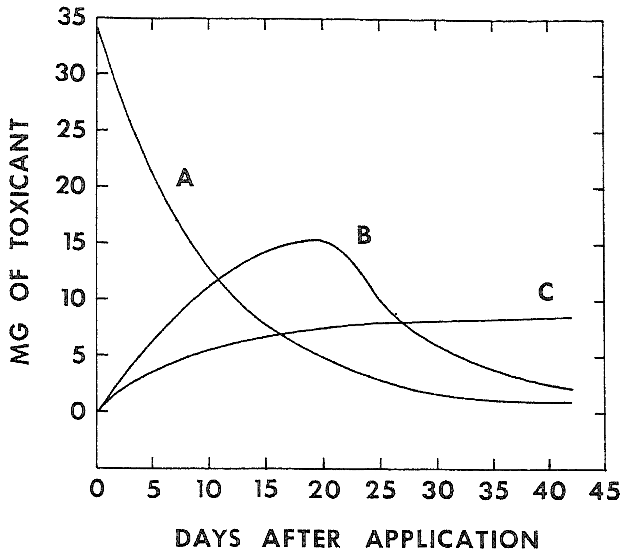

FIGURE 2.—Theoretical levels of toxicant remaining in soil after a soil application of (A) 34 mg of aldicarb in a single application, (B) 34 mg in equal daily doses for 20 days, and (C) 34 mg in equal daily doses for 42 days.

These projections show that a slow-release formulation may extend biological activity, but may not improve compounds with moderate or low insecticidal activity at normal application rates. Also, the effectiveness of slow-release formulations may be directly related to the susceptibility of a pest to the toxicant. At conventional application rates, the best slow-release formulation of aldicarb for the control of highly susceptible pests as cotton aphids and spider mites may be one which releases toxicant slowly over a long time, while the best formulation for a less susceptible pest such as the boll weevil may be one which releases toxicant faster over a shorter time.

BIOLOGICAL TESTS

The tests consisted of side-dress and in-furrow applications of various aldicarb formulations to cotton plants, followed by bioassays of plant parts with boll weevils, carmine spider mites, *Tetranychus cinnabarinus* (Boisduval), and cotton aphids, *Aphis gossypii* Glover. One test was conducted to evaluate the effects of different formulations on the germination and emergence of cotton seedlings at three temperatures.

The granular formulations, all containing 10% aldicarb by weight, were made from petroleum charcoal granules and corncob granules. The former contained 10%, 20%, and 30% water-insoluble binder supplied by Great Lakes Research Corp. and are referred to as PC–10, PC–20, and PC–30, respectively. Corncob granules, supplied by Union Carbide Corp., were prepared by absorbing aldicarb on 16–30-mesh corncob and coating the granules with a water-soluble wax. In general, the rates of toxicant release from the petroleum charcoal granules were inversely related to percentage of binder (*22*). The corncob formulation, the commercial preparation of aldicarb, was used as the fast-release standard.

In the first test, the aldicarb formulations were applied as a side-dressing at the rate of 340 mg of granules (34 mg of toxicant)/plant. The granules were distributed in four 2-inch-deep holes spaced evenly around cotton plants (12 to 14 inches tall) that were growing in 1-gal containers in the greenhouse. From 1 to 42 days posttreatment, new leaves (those formed since the preceding bioassay) and old leaves (those present at the time of treatment) were removed and fed to adult boll weevils held in ventilated glass containers. Mortality was recorded after 72 hours. Three replicates of 10 weevils were used in each bioassay, and the percent mortality was corrected to account for loss of weevils in the untreated check (*1*). The results of this test (table 1) indicated that the PC–10 and PC–20 formulations provided longer control of boll weevils than the corncob formulation. For example, at 42 days posttreatment, the mortalities of boll weevils fed new growth from cotton plants treated with the PC–10, PC–20, and corncob formulations of aldicarb were 46%, 25%, and 0% respectively. Similar results were obtained by Stokes et al. (*22*).

In the second test, 100 mg of the granular formulations (10 mg of toxicant) was applied with the cottonseed (6–8 seeds/gal container) at the time of planting. When the first true leaves formed on the cotton plants (about 2 weeks after planting), bioassays with boll weevils, cotton aphids, and carmine spider mites were initiated. The boll weevil bioassays were conducted as described for the first test; the cotton aphids were caged on individual leaves with clip-on cages, and the spider mites were restricted to individual leaves by encircling the leaf petioles at the base with an adhesive. Four replicates of about 25 aphids or 50 spider mites were used per treat-

TABLE 1.—*Systemic toxicity of granular aldicarb formulations to boll weevils*

[Side-dress treatment at 34 mg toxicant/cotton plant]

Formulation	Percent mortality[1] after —					
	7 days	14 days	21 days	28 days	35 days	42 days
	Weevils fed old growth					
PC–10	93	96	100	91	92	84
PC–20	82	96	100	87	64	52
Corncob	100	100	95	100	16	24
	Weevils fed new growth					
PC–10	85	79	84	84	64	46
PC–20	32	55	76	65	42	25
Corncob	100	79	96	57	17	0

[1] Expressed as the average of 3 replicates.

ment. The actual numbers of aphids and mites in the checks were used to calculate mortality. None of the formulations tested appeared to increase the length of effectiveness of aldicarb against the boll weevil (table 2). At the applied dosage, all treatments resulted in low boll weevil mortalities. However, the petroleum charcoal formulations were more effective against the cotton aphid and the carmine spider mites than the corncob formulation. In fact, the PC–20 and PC–30 formulations almost doubled the length of insect control. For example, at 36 and 71 days posttreatment 56% and 0% reductions of aphids occurred on plants treated with the corncob formulation. In comparison, the PC–20 and PC–30 formulations provided essentially 100% control of aphids at 36 days posttreatment and 58% or better aphid control for 71 days.

TABLE 2.—*Systemic toxicity of granular aldicarb formulations to boll weevils, aphids, and spider mites*

[In-furrow treatment at 10 mg toxicant/pot]

Formulation	Percent morality after —		
	22 days	36 days	71 days
	Boll weevils[1]		
PC–10	30	18	0
PC–20	48	29	0
PC–30	39	28	0
Corncob	30	22	0
	Aphids[2]		
PC–10	100	100	0
PC–20	100	100	58
PC–30	100	99	65
Corncob	100	56	0
	Spider mites[2]		
PC–10	97	93	62
PC–20	97	74	89
PC–30	97	41	74
Corncob	95	27	0

[1] Expressed as the average of 3 replicates.

[2] Expressed as the average of 4 replicates of approximately 25 cotton aphids or 50 spider mites/replicate.

If the formulations provide toxicant through delayed release as suggested in figure 2, they should also reduce the adverse effects of aldicarb on emerging seedlings. To investigate this possibility, acid-delinted cottonseed was planted in metal trays containing 5 lb of air-dried Lakeland fine sand. Granules of the corncob, PC–10, and PC–20 formulations were added to the seed furrows in amounts equal to 1, 2, and 4 lb of toxicant/acre. Sixteen seeds were planted one-half inch deep in each tray. Four replicates of each formulation and application rate were placed in separate temperature cabinets maintained at 20± 1°, 25± 1°, and 31± 1° C. A moisture level 75% of field capacity (3.75% by weight) was maintained by weighing the trays daily and adding water as needed. Emerging plants were counted daily until the time of maximum emergence (11 days at 25±1° and 31±1° C and 14 days at 20±1° C). The corncob formulation was more deleterious to plant stands than the other two formulations (table 3). For example, at an

TABLE 3.—*Percent emergence of cotton seedlings at three temperatures following in-furrow applications of granular aldicarb formulations*[1]

Formulation	Application rate (lb/acre)		
	1.0	2.0	4.0
		20° C	
Control (untreated)	88	88	88
PC–10	68	48	19
PC–20	91	88	42
Corncob	30	5	3
		25° C	
Control (untreated)	94	94	94
PC–10	73	47	14
PC–20	95	58	22
Corncob	48	17	3
		31° C	
Control (untreated)	94	94	94
PC–10	70	42	5
PC–20	95	58	25
Corncob	64	42	3

[1] Results are the average of 4 replicates of each formulation at each temperature level.

application rate of 2 lb of toxicant/acre and a holding temperature of 20° C, plant emergence was 48%, 88%, and 5% following treatment with the PC–10, PC–20, and corncob formulations, respectively. At this temperature, plant emergence in the untreated check was 88%. Similar results were obtained with all dosages at 25° C; however, the three formulations could not be separated on the basis of plant stand damage at 31° C.

CONCLUSIONS

The results of the biological tests conducted under controlled conditions in the laboratory and greenhouse appear to substantiate the projections made with the models. When the granular formulations of aldicarb were applied to cotton at 34 mg of toxicant/plant, the petroleum charcoal (slow-release) formulations were more effective against the boll weevil than the corncob (fast-release) formulation. However, when the granular formulations were applied at the rate of 10 mg of toxicant/pot (4 to 6 plants/pot), the petroleum charcoal formulations were no more effective against the boll weevil than the corncob formulation, but were almost twice as effective against the cotton aphid and carmine spider mite.

Our results and the results of previous tests (*21, 22*) suggest that slow-release formulations of aldicarb are feasible and that they should control target pests over a longer time without any increase in toxicant. Also, these formulations should be safer to handle than conventional ones because the incorporated insecticide is distributed within the granules, which must be held in moist soil (or water) for several hours before all toxicant is released.

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